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USE OF INFRARED AERIAL PHOTOGRAPHY IN DETECTING AREAS WITH EXCESS SURFACE WATER AND GROUND WATER OUTFLOWS

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USE OF INFRARED AERIAL PHOTOGRAPHY IN DETECTING AREAS WITH EXCESS SURFACE WATER AND GROUND WATER OUTFLOWS

by

B. V. Shilin, N. A. Gusev, and Ye. Ya. Karizhenskiy*

When hydrogeological studies are made from aircraft, today mainly aerial photography is employed. The boundaries of water-saturated and water-impermeable strata are traced on aerial photographs; increased surface-water zones are contoured, and so on. All these manifestations of ground water are interpreted mainly from the results of their activity, that is, by indirect features. For example, outflows of water are interpreted along funnels or erosion furrows; the boundaries of lithological rock differences, since they are indicative hydrogeological boundaries, are determined by the position of fine erosional forms, and so on. In the absence of noticeable traces of ground water activity, the presence of ground water near the surface is interpreted by the nature of the vegetal cover, soil types, and so on.

In contrast to aerial photography, infrared (IR) aerial photography -- since it studies the intrinsic thermal radiation of terrain elements (mainly in the spectral ranges 1.8-5.3 and 7.5-14 microns) -- permits the

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interpretation of hydrogeological objects based on a direct feature -- increased surface water.

Infrared aerial photography yields information on changes in the surface water content of surface areas based on their temperature. This affords direct detection of moisture independently of traces of ground water activity. This is because ground water flowing out to the surface is usually at a temperature different from that of the surrounding surface.

Actually, IR aerial photography establishes temperature contra ts of a locality. Modern high-sensitivity flight equipment provides IR images that are close in quality to those of ordinary aerial photographs. The physical principles underlying the method, existing equipment, and examples of the use of IR aerial photography in the surveying of natural resources have been treated in a number of works by Soviet and foreign authors [1, 2, 3, 4, 5, 6, 7, 8].

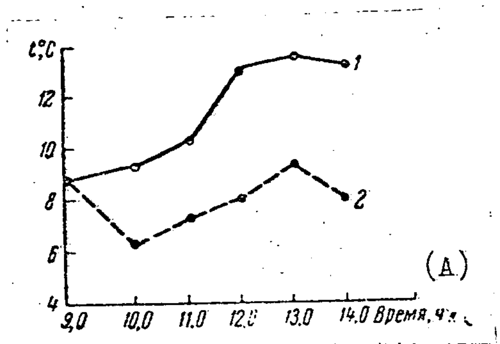


Fig. 1. Soil temperature of sections with different moisture content
1 -- dry section 2 -- moist section (measurements taken by Ye. I. Vavilov)
KEY: A -- time, hours

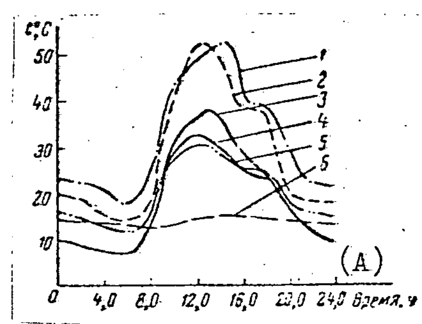


Fig. 2. Diurnal changes in temperature of terrain elements [8]
1 -- asphalt 2 -- soils on top of granite
3 -- grassy meadow cover 4 -- meadow covered with reeds and grass
5 -- branches of conifers 6 -- river water
KEY: A -- time, hours

Fig. 1 shows variation in soil temperature in areas with different surface water content; one section was periodically subjected to artificial irrigation. In the morning hours after sunrise and prior to irrigation, the temperature of the areas was the same. Right after irrigation the temperature of the wet area began to drop sharply (the effect of evaporation), while the temperature of the dry area rose due to solar heating. Then the temperatures of both sections began to be equalized, but differences of 3-4° were maintained. Similar correlations are found when analyzing diurnal fluctuations of temperature of various terrain elements (Fig. 2).

In the evening and night hours, variations in the temperature of terrain elements occur very slowly. On cold clear nights, changes in the water-land contrasts become inverted due to the slow cooling of water. These contrasts are particularly large during the first half of the night, and by dawn they become equalized. On hot cloudy nights, the temperature of terrain elements levels off and the inversion of the water-land contrast often practically disappears. Thus, in Fig. 2 the inversion was observed only with respect to meadow vegetation and conifers. However, it must be borne in mind that here the temperature of flowing river water, marked by slight diurnal changes, is presented for sake of comparison in this figure.

When IR images are subjected to hydrogeological interpretation, one must also bear in mind the important role of the radiation of vegetation. Under otherwise equal conditions, on warm summer days thermal radiation of vegetation for soil that is moisture-rich is less than for vegetation growing in dry soils, since the vegetation adjusts its temperature by evaporation.

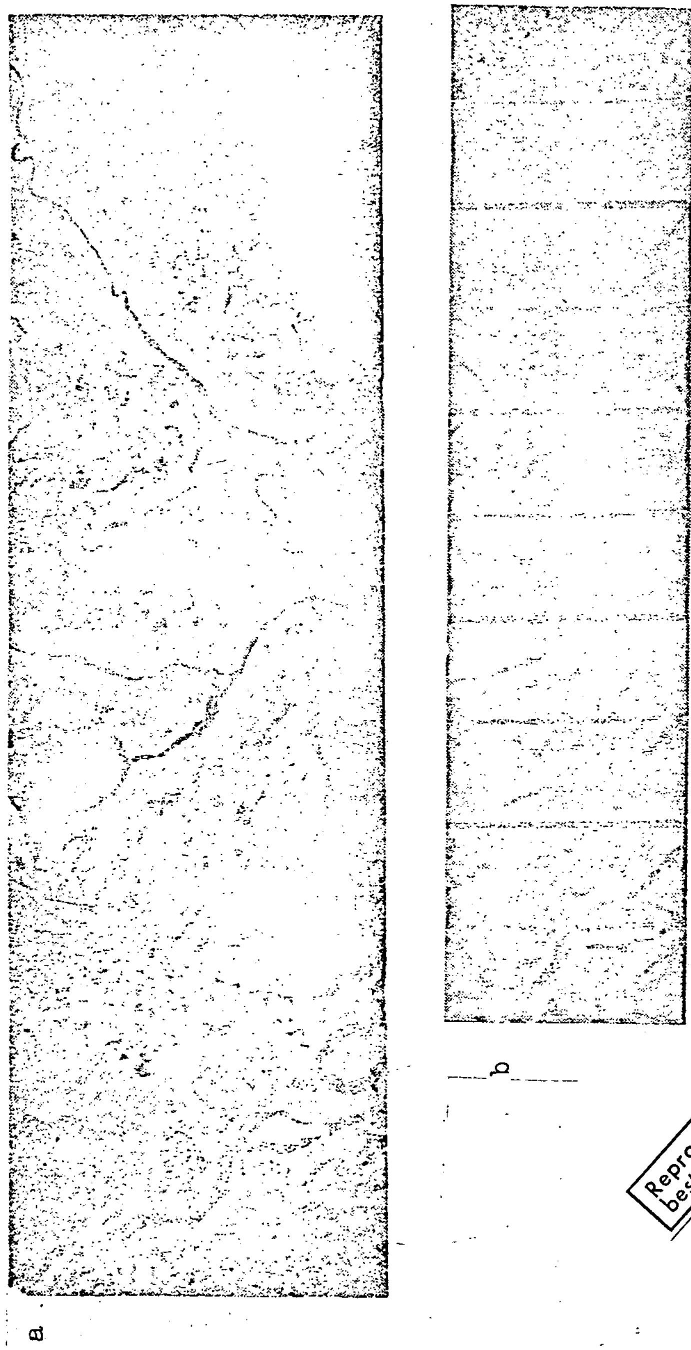
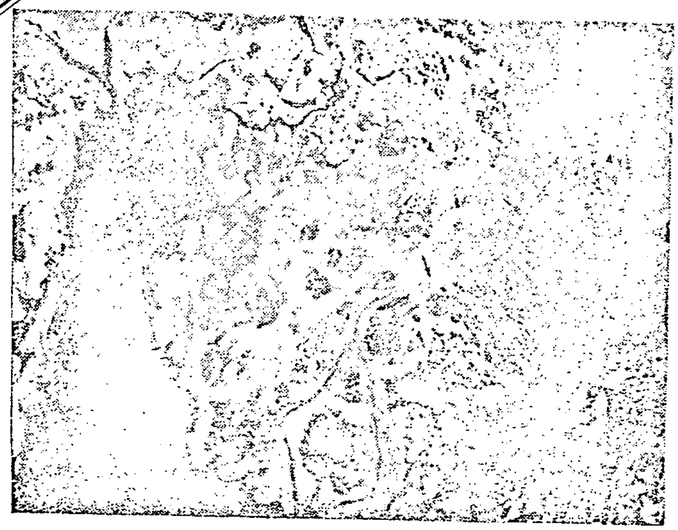


Fig. 3. Vertical aerial photograph (a) and IR image (b) of the swampy shore of a crateral lake (time of photography 10 hours, 50 minutes, spectral range 3.2-5.3 microns, and flight altitude 400-500 m)

a



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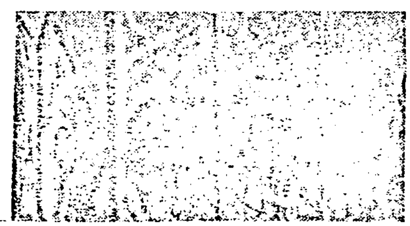

Fig. 4. Vertical aerial photography (a) and IR-image (b) of part of a swamp terrain (time of photography 12 hours 30 minutes, spectral range 3.2-5.3 microns, and flight altitude 500 m)

Fig. 3 presents a vertical aerial photograph and an IR-image (about 1:13,000 in scale) of part of a flooded shore of a crateral lake. Cold (warm) moisture-rich sections are more clearly delineated on the IR-image obtained before noon. Small swamps in the mouths of streams are especially clearly evident. Fig. 4 presents a vertical aerial photograph and an IR-image a

b

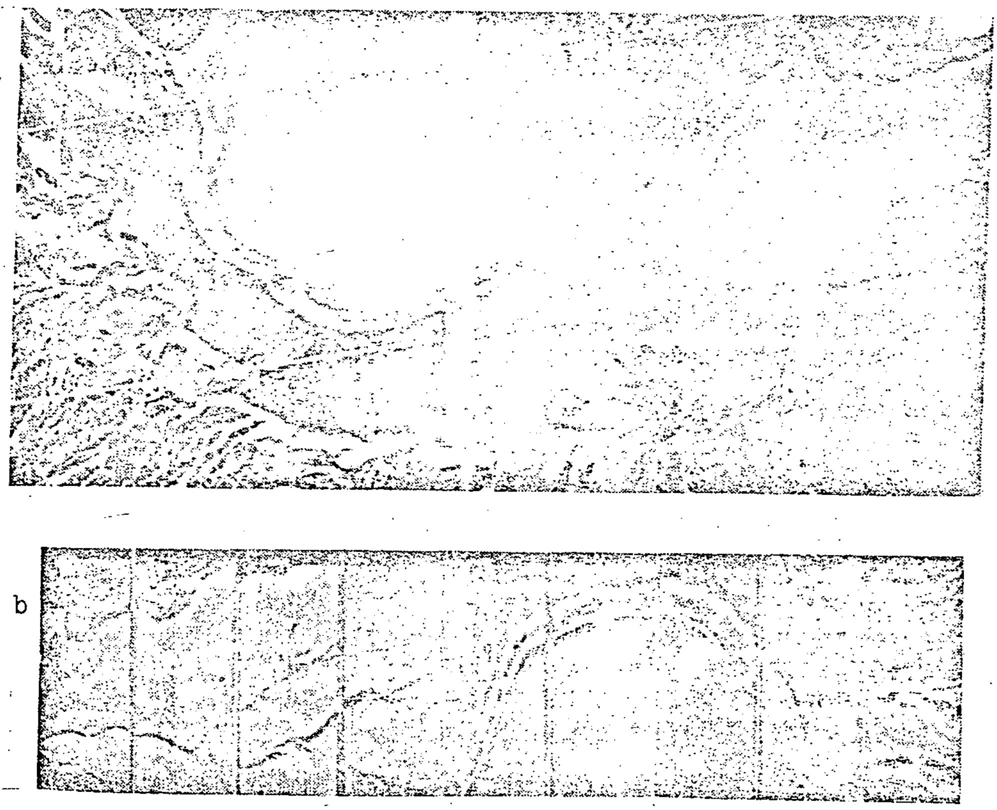

Fig. 5. Vertical aerial photograph (a) and IR-image (b) of part of the tundra terrain (time of photography 10 hours 30 minutes, spectral range 3.2-5.3 microns, and flight altitude 800 m). Cold-water springs and a section of the hore declivity with the outflow of a water-bearing stratum are shown on the IR-image.

(on the same scale) of a swampy depression completely covered over with sedge thickets. In the aerial photograph, a small channel is practically indistinguishable against the even background of the swamp, while on the IR-image against a background of sun-heated grass -- compare (cf. Fig. 2) curves for water and meadow grass recorded at 12 o'clock noon, it is very clearly visible (indicated by arrows).

In Fig. 5, zones with increased surface water and a number of outflows of ground water in the middle of tundra terrain (scale about 1:18,000) have been interpreted. Two cold-water springs close to a brook, defined with difficulty in the aerial photograph, can be seen in the IR-image as clear black patches. Sections in dark photographic tone stand out on the shore declivity brightly illuminated by the sun. As an analysis of the aerial photograph showed, these sections are overgrown with Japanese stone pine. However, in the upper left corner of the lake (marked on the photograph), the dark photographic tone of the IR image corresponds to a section of exposed declivity. Here cooling can be associated only with evaporation from surface water-intense areas. A ground check confirmed this conclusion: a water-saturated stratum of loose coarse-fragment bombs and volcanic slags was detected.

A more exact analysis is required for the vertical aerial photograph and the IR-image (about 1:18,000 in scale) of part of the poorly articulated swampy terrain containinng a lake in its upper region, shown in Fig. 6. The entire ground surface is covered with uniform tundra vegetation and we cannot state with certainty that outflows of ground water are present here. Only in the center of the image and along the lake shores does the presence of continuous sedge thickets indirectly evidence increased moisture content. In the left part of the aerial photograph there are no hydrogeological indicators at all. On the IR-image, in its left part around the dark (cold) areas several ground water outflows feeding the swamped creek flowing into the lake can be readily interpreted. In the central part of the image a dark section of the swamp is discernible, evidently fed from the influx of ground water.

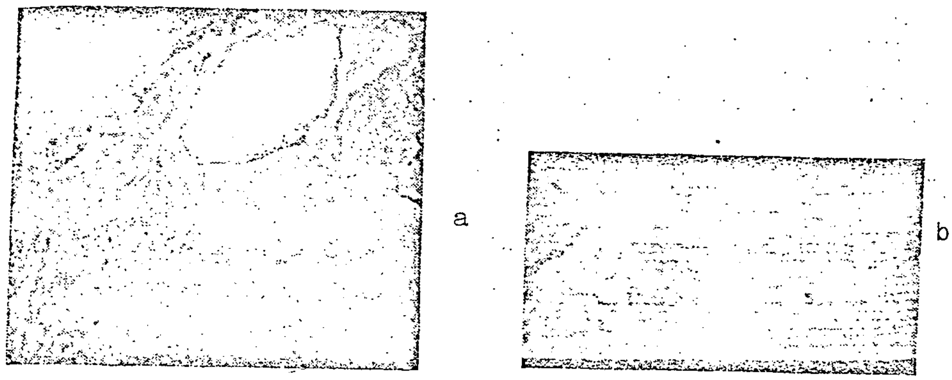

Fig. 6. Vertical aerial photograph (a) and the IR-image (b) of part of the tundra terrain (time of photography 10 hours 25 minutes, spectral range 3.2-5.3 microns, and flight altitude 700 m)

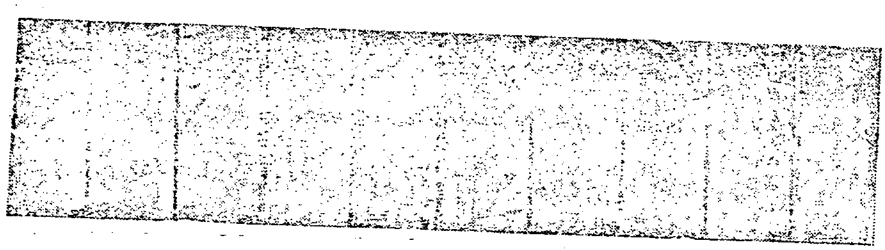

Fig. 7. Infrared image of the swamped delta of a large river with inflowing tributaries (time of photography 23 hours 00 minutes, spectral range 1.8-5.3 microns, and flight altitude 400 m)

Elements of hydrogeology and hydrology are exceptionally clearly delineated on the IR-image (about 1:10,000 in scale) obtained on a cold autumn night when the ground became wet very rapidly and the temperature of the wet sections and the water surface exceeded the land temperature due to the greater thermal inertia of water (Fig. 7). The water temperature in the river was about 7°, while on land frosts were observed by morning.

These examples do not exhaust the diversity of natural and technical conditions for the use of IR aerial photography in hydrogeological studies. Still, they quite forcefully demonstrate its possibilities in this application and the urgency of further advances in techniques. This latter imperative stems from the need to determine the optimal conditions for IR aerial photography when carrying out specific hydrogeological missions in different geological regions and terrain-climatic zones. The introduction of the technique is particularly important when searching for ground water in desert and semi-desert zones.

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